

Stability offers unique opportunity for research

Colin Macilwain

On 13 January this year, Brazil suffered a shock which, if you listen to some commentators abroad, shook it to its very core. In São Paulo the following week, however, the locals were unfazed. By Latin American standards, a devaluation of 25 per cent (later 45 per cent) is not much to get excited about. In the bustle of São Paulo's business district, in its universities and medical schools, in the halls of Congress and government buildings across Latin America, and, most significantly of all, in the military barracks, life continues much as it did before.

That new stability is the story of Latin America at the approach of the millennium. For the first time since the nations of the region were founded by Spanish and Portuguese colonists, most enjoy the political and economic conditions that could enable science to prosper. Although some of the military governments that used to govern in the region were quite generous to science — the last Brazilian regime of the early 1980s, for example — their hostility to free thought in general and to universities in particular made it impossible for this to happen.

Political transformation

Although concerned about money, dilapidated campuses and the slow delivery of materials, scientists in the region have an unrivalled opportunity to improve their situation. The fall of the military dictatorships in Argentina, Brazil, Chile and elsewhere, and the gradual unravelling of Mexico's *de facto* one-party state, have been followed by a period of relative economic and political stability. Notwithstanding the recent travails of the Brazilian *real*, this stability gives long-term enterprises, such as scientific research, a greater opportunity to prosper.

Yet among scientists in the region, there is no universal recognition that such an opportunity exists. Most of the larger nations there have enjoyed impressive economic growth over the past ten years, but intellectuals, including scientists, tend to deride this achievement. In particular, they regret the passing of the large, self-sufficient but woefully uncompetitive industrial base that existed behind the trade barriers of the old Latin American economy.

The role of science and technology was clear in that economy: science would support the technology which would build a domestic industrial base which would haul the region into the developed world. But

much of this industry was essentially uncompetitive, and when exposed to the winds of international competition, it collapsed. Factories and enterprises have been sold to multinational corporations who are modernizing them with technology imported from abroad. Home-grown science and technology has yet to establish its role in this new arrangement.

At organizations such as the World Bank and the Inter-American Development Bank, which strongly influence science policy in the region, economists have generally responded to the change by advocating more emphasis on technology development, and less on scientific research. Political leaders, from the science ministers of Brazil and Argentina down, are lecturing scientists about the importance of 'applications'.

In a manner familiar to students of the history of 'development' in the Third World, this idea is being dispensed several years after it has fallen out of fashion in the United States, where basic research is the government's top priority, and in Europe, where 'applied research' efforts such as the early Framework programmes have scored few notable successes in spawning industrial innovation.

Fortunately, there is a second strand running through science policy in the region: the advent of a more ruthless and elitist approach to selecting scientists for support. Whereas governments once sought to expand their scientific communities by distributing money as widely as possible, they are becoming more willing to upset the apple-cart and back the people who are really doing good work. Argentina, Chile and the federal government in Brazil all have efforts underway that provide fairly impressive resources to small numbers of investigators. The Howard Hughes Medical Institute, based in the United States, has singled out a small group of 27 of the best life scientists in the region for substantial support for five years. A Chilean proposal for Millennium Institutes would take the principle even further, assuring long-term and generous support for a very small number of internationally selected groups.

With governments pushing for applied science and taking a more selective approach to basic research, some scientists are clearly feeling the squeeze. However, the total investment in basic science, although difficult to measure and subject to short-term fluctuation, has been increasing gradually.

In any conversation with scientists in almost any Latin American country, two problems come up again and again: lack of resources and slow access to materials. Both may ease over time, with economic growth and the lifting of customs barriers, respectively. But both are largely beyond the control of either the scientists or the science ministries.

Five problems to be confronted

For the scientific community itself, there are some more accessible problems that need to be tackled. In ascending order of difficulty, these are: a reluctance to accept outside peer review; the lack of regional integration in science; scientists' grudging acceptance of the free market; the pressing need for university reform; and a failure to acknowledge the importance of intellectual property rights in modern research.

Peer review in the countries that account for most scientific activity in the region is basically honest. However, in today's world of intense specialization, most scientific sub-disciplines in Brazil, never mind in the smaller countries in the region, are simply too small and close-knit to allow for objective peer review from within.

Yet when it is suggested that experts based abroad should be involved in peer-reviewing grant proposals, some scientists respond as though their country's sovereignty were being impugned. In fact, international peer review is a valuable, inexpensive tool for improving the quality of scientific programmes.

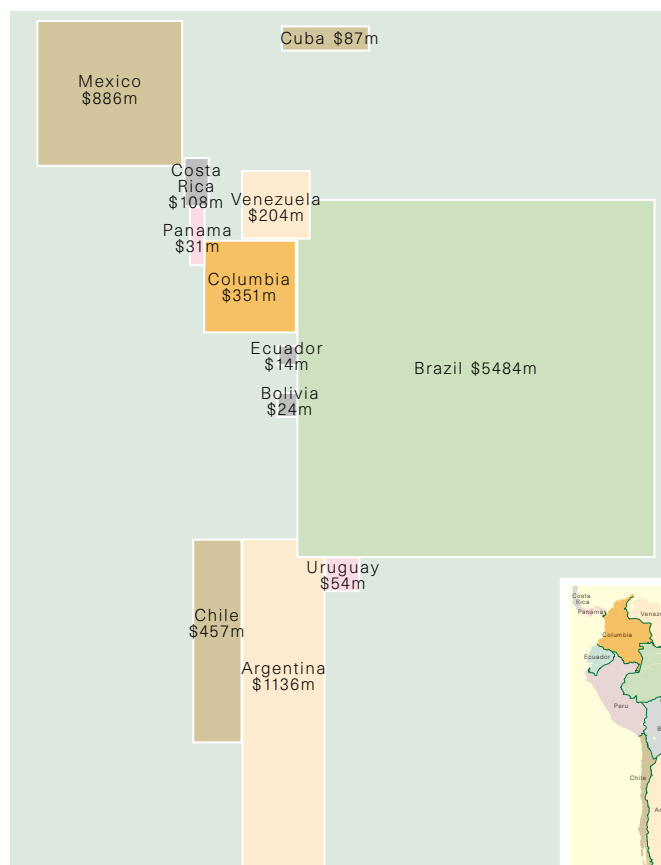
Most senior scientists in the region were trained in the United States or Europe and it is there that they turn first to build scientific collaboration. "Usually our links are with powerful institutions in the United States or in Europe," says José Maza, head of astronomy at the University of Chile, who points out that collaboration between two developing countries is more difficult to accomplish: "It is hard to coordinate things when you have problems at both ends of the line."

This lack of collaboration within the region — which governments counter with words, but little action — is needlessly constraining the development of better human networks that could increase the competence and confidence of the region's best research groups, all of whom complain of their isolation.

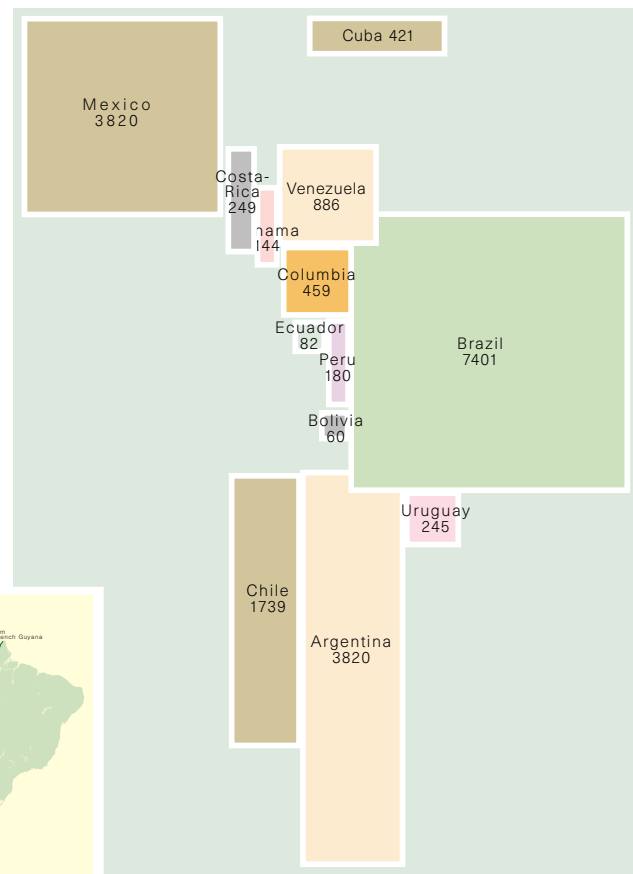
Many scientists, as well as politicians, assume that more economic integration, predominately through the trade group Mercosur, has to come before greater scientific integration. But scientists could act now. "We should look at the continent as a unit scientifically," says Francisco Claro, the dean of research at the Catholic University in Santiago, Chile, stressing the inclusion of Mexico in such a strategy. "Science could be the success story for integration."

The free-market ideology that has, depending on how you look at it, either been





Brazil, with its large industrial base, claims to spend far more on R&D than the rest of the region combined . . .



. . . but in terms of scientific papers published in ISI journals, other countries muster a strong presence.



imposed upon the region by the United States since the end of the Cold War, or been implemented by its newly democratic governments, has been no more warmly welcomed by academics in the region than it was by dons at Oxford, when they famously refused to grant Margaret Thatcher the honorary degree to which British prime ministers are accustomed.

It is understandable, and indeed necessary, that academic scientists are resisting free-market rhetoric to the effect that industry, and not government, should pay for university research. "This is nonsense," as Leopoldo de Meis, a prominent biologist at the Federal University of Rio de Janeiro, points out. "Even MIT gets 85 per cent of its research funds from the government." However, there remains a truculent anti-commercial bias in the universities which, until it dissipates, is going to constrain their relevance to the world beyond their gates.

And it is not just anti-commercial sentiment that threatens the position of the research universities of Latin America. Some of the institutions themselves are chiefly dedicated not to research or to teaching, but to self-preservation.

In countries that have never enjoyed genuine and stable democracy, it is of course necessary for the universities to jealously protect their autonomy. But hard-working staff at the universities themselves now resent the

extent to which they are surrounded by people who do nothing but draw a salary. As democracy solidifies, it will become possible for university administrators to do something about this without their actions being equated with those of military thugs. In the meantime, a steady increase in the methodical evaluation of university departments (being pioneered at both the University of São Paulo and Mexico's National Autonomous University), and the encouragement of a greater diversity of research universities, both public and private, will help to create a healthier research environment.

Finally, that environment will require rapid progress towards a recognition of intellectual property rights and their importance in modern research. Brazil produces about 1 per cent of the science published in international journals — the same proportion as Korea. But whereas Korea also generates 1 per cent of all of the patents filed at the United States patent office, Brazil files one-fiftieth of 1 per cent. The biggest research university in Mexico has appointed a chief patent officer (see page A7), but he expects scientists to fund patent applications from their own pockets — even though the patents will be held by the university.

Many scientists in Latin America will read all this and say: fine and good, but none of it is going to change. A lot of them were educated in the wealthy research universities of the

United States and are frustrated by the day-to-day challenges they now face. But the opportunity that they have as a community is real and, despite Brazil's devaluation, unparalleled in Latin America's history. This is best grasped, perhaps, by those young enough to lack cynicism, or old enough to know how much things have already improved.

Moyses Nussenzweig, a veteran physicist at the Federal University of Rio de Janeiro, has had extensive input into the country's science policy since returning there in 1975 after 12 years in the United States. He never regretted going back, and looks to the future with determined optimism. Nussenzweig has witnessed the progress already made: he has seen the physics community expand dramatically, to perhaps 2,000 physicists, and the percentage of Brazilian papers in *Physical Review Letters* double in the past ten years. Science in Brazil, he says, "has become much more professional."

His determination is shared by the young men and women who will carry the banner forward for science in the region. "It's not so good here," admits Diego Comerici, a graduate student at the Institute of Biotechnology at the National University of General San Martín in Buenos Aires. "There are great difficulties in doing science, economic problems and problems with national politics. But I think that things will change. We will fight to change them."

Scientists see support from Mexican public

Laura Garwin

Last year, Luis Herrera-Estrella thought he saw an opportunity to use his science to contribute to Mexico's economy. Herrera-Estrella, a plant biologist at the Centre for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV), was one of several scientists invited to a meeting with tequila producers. The subject: the country's dwindling populations of agave, the plant used to make tequila. Although Mexican exports of tequila have soared, agaves have been succumbing to disease, and the tequila producers decided to seek help from scientists.

At the meeting, organized by Mexico's research council, CONACYT, Herrera-Estrella told the producers that for US\$500,000 he could develop transgenic agave plants that would be resistant to disease. Moreover, CONACYT would pay half the cost. The offer was a bargain: the producers had previously approached scientists at a well-known US agricultural biotechnology company, who had said that if they were interested in the project — which wasn't certain — it would cost the producers more than \$20 million.

But the producers rejected Herrera-Estrella's offer — in his words, "they said I was crazy to ask for half a million" — despite knowing that a US scientist would charge much more for the same service, and despite the fact that \$200 million a year in exports was at stake. "Industrialists think that because we're Mexicans, we should charge what Mexican labourers charge," says a physicist who has found himself in a similar situation. "They would rather pay more for something 'safe', from abroad."

A history of science in isolation

This lack of confidence in the country's own scientists pervades Mexican industry and is one of the many hurdles that Mexican science must overcome if it is to be treated as a tool for the country's development, rather than as an optional extra. Many scientists feel that, despite President Ernesto Zedillo's repeated public assurances of the importance of science and technology, there is no real acceptance of this importance by those in power, or by the wider public.

Part of the problem is cultural. Mexico has inherited the European tradition of scientist as academician, rather than the US model of scientist as inventor and entrepreneur.

As one astronomer put it, "Here, to use your brain is respected; to use your hands is not." For a university scientist to have links with industry is to risk the charge of "prostitution" from colleagues; traditionally, university contracts allow only minimal time for consulting or other outside work.

Moreover, a large proportion (sometimes over 50 per cent) of a scientist's salary can come from supplements — administered by research institutions and by CONACYT — that are tied closely to the number of publications in international, refereed journals. Doing proprietary work for industry is often incompatible with publication, and — as one applied physicist put it — "not many international journals will accept papers on the problems of Mexican industry."

On the side of industry, there is no strong tradition of investing in research and development (R&D), either in-house or in the universities. Until the early 1980s, Mexico had an industrial policy of state ownership and protectionism, giving Mexican industry little incentive to invest in innovation. Now firms are interested in modernizing their technology, but are more likely to turn to foreign companies for assistance.

"We haven't been able to convince Mexican industry that we can produce technology with the speed and quality that they need,"



says Miguel José Yacamán, the director of the Ministry of Energy's institute for nuclear research. "Firms can't wait for a scientist to take two years to modernize a plant — so they just buy technology from the United States."

Forging new links with industry

With increasingly widespread recognition of the need for scientists to show that they can solve practical problems, programmes are emerging throughout the research establishment to facilitate closer ties with industry. For example, the rector of the National Autonomous University (UNAM), Francisco Barnés, has established a university liaison office, to foster collaborative research on problems that are important for national development. Barnés — who himself has links with industry, having previously been the director of the Ministry of Energy's petroleum research institute (IMP) — was also instrumental in setting up a new National Laboratory for Rheology and Applied Mechanics, jointly funded by UNAM and the IMP. This laboratory, which will work on problems related to the exploitation of petroleum and underground water resources, is expected to inspire successors, addressing other problems of national importance.

Meanwhile, CONACYT plans this year to



This pilot fermentation plant for producing yeast from molasses was built at CINVESTAV in 1990 — a time when, one physicist says, "the government wanted to transform universities into factories".

CINVESTAV-IPN

remove the salary disincentive for doing applied research, by broadening the qualification criteria for its salary supplement scheme to include patents, contracts with industry, new software and the like, as well as peer-reviewed publications.

CONACYT is also trying to promote applied research through its system of 27 research centres, funded by the Ministry of Education (SEP). "Our main concern is to show society that science can be applied, so people will understand the power of science and technology," says Alfonso Serrano, an astrophysicist who is CONACYT's associate director for the SEP-CONACYT centres. Last year, scientists in the centres did work for 9,000 companies, Serrano says, and 30–40 per cent of the total budget of the system came from external sources.

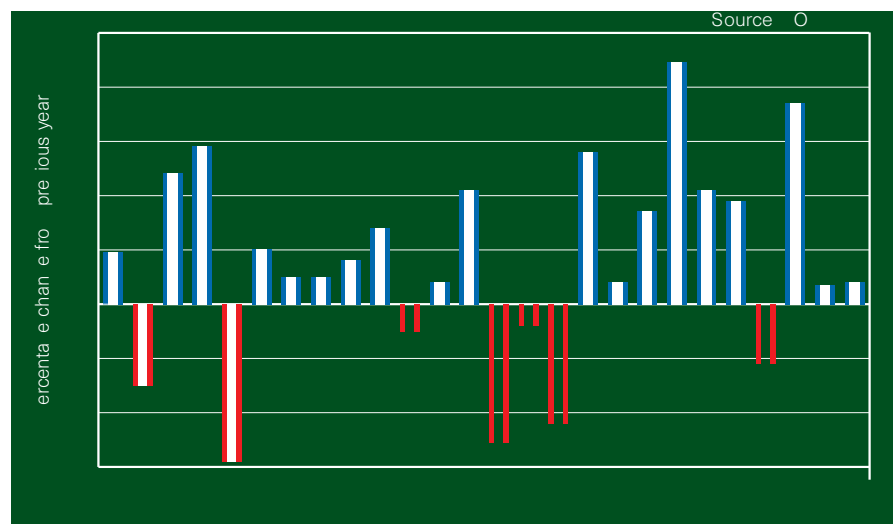
Serrano is proud that in 1997, one of the SEP-CONACYT centres (the Applied Chemistry Research Centre, in Saltillo) submitted seven Mexican patent applications — as many as were generated by the 1,100 research scientists of UNAM. This may say less about the inventiveness of UNAM scientists than about the bureaucratic difficulties they have faced in trying to patent their work — one UNAM physicist tells of an application that sat on a desk in the university patent office for three years.

CINVESTAV, Mexico's other top research institution, with around 530 research scientists, has a similarly small number of patents — only 30 Mexican ones granted since 1970, and three applied for in 1997. But the director of CINVESTAV's planning office, Manuel Méndez, hopes to increase this activity and plans to create a "proper technology transfer office", to help the centre's scientists in their dealings with industry.

Funding collaboration

All of these efforts to promote ties between academia and industry will receive a substantial boost from a \$300 million loan to Mexico from the World Bank, approved last June. The loan, together with \$210 million from the Mexican government and \$150 million from the Mexican private sector, will be used to finance a five-year Knowledge and Innovation Project, which will constitute about one-third of CONACYT's funding during that period.

About 60 per cent of the project's \$660 million total cost will be spent on furthering the links between academia and industry, and on technology support for firms; the rest will fund academic research, but with a portion reserved for fields of 'high scientific, economic and/or social relevance to Mexico'. The component of linkage will include the restructuring of most of the SEP-CONACYT research centres, to encourage them to raise more funds from the private sector; the support of joint academic-industrial applied research projects; and the



Funding for research projects from Mexico's CONACYT has been subject to fluctuations.

creation and strengthening of university outreach units.

Traditionally, most Mexican scientists have been wary of government attempts to direct research towards national needs — with only about 6,000 full-time researchers, one argument goes, the community is too small to focus on anything other than excellence in research, and training young scientists. The reaction against targeted research has probably been strengthened by some rather heavy-handed government policies in the past. Julio Mendoza, a physicist at CINVESTAV who works on optoelectronics, remembers when, in the 1980s, "the government wanted to transform universities into factories," with pilot plants on university campuses. "People had trouble adjusting," says Mendoza, "so they just put their heads down until times got better."

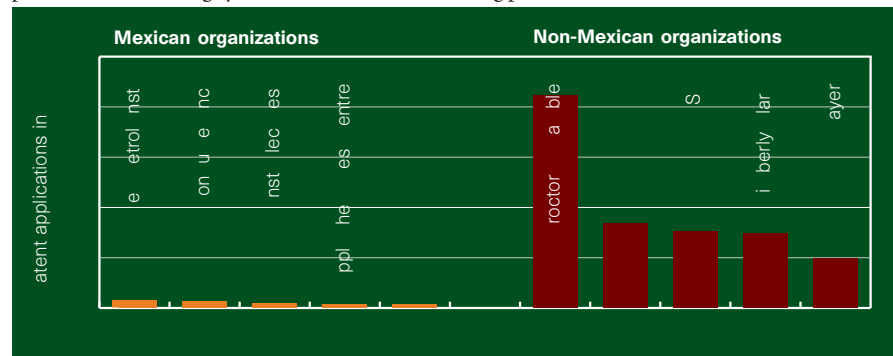
Mayra de la Torre, a biotechnologist at CINVESTAV, also remembers the time of the pilot plants. In 1984, the centre's director recalled her to Mexico from a postdoctoral fellowship in Zürich, to design and build a fermentation pilot plant. Then, encouraged by the director to sign contracts with industry, she undertook a project for the labour unions of the sugar industry, to develop alternative uses for sugar cane. Over five years, she developed a high-productivity process for making yeast from molasses,

built a production plant, and had started to develop processes to make human food from the yeast, when government policy changed. In 1991, the government and the unions sold the sugar companies, and the new owners were not interested in de la Torre's plants, so the technology went no further.

Furthermore, the government was no longer interested in having scientists work with industry. Now, the pendulum has swung back again, in a process that de la Torre thinks is destructive to the research enterprise. "From 1991 to 1998, the government worried about excellence in research — publications in international journals and the *Science Citation Index*," she says. "Now they want academics and industry to work together again. We don't have any equilibrium."

Stabilizing the policy swings

One source of disequilibrium is the Mexican electoral system, which promotes discontinuity by forbidding the re-election of presidents and members of Congress. Officials at CONACYT hope that the Knowledge and Innovation Project will lend some stability, not only by the infusion of hard currency, but also because its span (1998–2003) bridges two presidential terms. CONACYT has also damped a potential pendulum swing between basic and applied science by resisting pressure from the World Bank to devote a



Mexican patent applications from Mexican organizations are dwarfed by applications from abroad.

greater proportion of the project's funds to applied science.

Another force for stability comes from a recently formed alliance among CONACYT and two bodies representing the scientific community: the president's Science Advisory Council (CCC) and the Mexican Academy of Sciences. This alliance produced the text of legislation overhauling Mexico's system of research funding (see *Nature* 397, 553; 1999), and also helped to obtain a 1997 presidential decree exempting research materials from import taxes.

CONACYT itself seems to have a programme — often newly minted — to address almost any gripe that one hears from the community. Do young scientists have difficulty setting up laboratories? Last year, CONACYT set up a programme of infrastructure grants for young scientists. Is peer review within Mexico inadequate? CONACYT is considering increasing the number of reviews from Spanish-speaking scientists abroad. Do new fields have trouble gaining a foothold? The Knowledge and Innovation Project has a special programme of support for emerging fields.

Escaping a vicious circle

But as well-intentioned and energetic as CONACYT officials may be, they can do little in the short term about the problem that surfaces in just about every conversation with a Mexican scientist — the small size of the Mexican research community. In a country of almost 100 million people, to have only around 4,500 researchers in natural sciences and engineering is unfortunate, but to be producing only about 300 PhDs a year in these fields is simply depressing. Many scientists identify a vicious circle, comprising a research community that is too small to solve national problems, leading to a lack of public support for science, which in turn prevents growth of the community.

President Zedillo's administration, and the World Bank, are hoping that private-sector investment in R&D, coaxed into life by the Knowledge and Innovation Project, will provide the missing ingredient that turns the vicious circle into a virtuous one. The administration's six-year plan for science and technology made a commitment to increasing R&D spending from 0.32 per cent of the gross domestic product (GDP) in 1995 to 0.7 per cent in 2000 — but it envisaged that additional spending by industry would account for two-thirds of this increase, rising from 18 to 45 per cent of total R&D spending. (In the United States, industry accounts for

Centre fights fixation with basic research

The challenge of combining high-quality basic research with a mission to address the country's wider needs is embodied in the experience of UNAM's Nitrogen Fixation Research Centre, in Cuernavaca. The centre was founded in 1980 with the aim of studying the molecular basis of biological nitrogen fixation, and applying this knowledge to improve agriculture.

For the Mexican farmer, fertilizer is expensive to buy and transport, and its overuse is a significant environmental problem. Fertilizer use could be greatly reduced if the symbiosis between legumes and nitrogen-fixing bacteria could be improved or extended to crop plants other than legumes. And ultimately, if genetic engineering could give plants their own nitrogen-fixing apparatus, the need for bacteria could be eliminated.

In basic science, the centre has fulfilled its promise: its scientists have made important contributions to understanding the dynamics of the bacterial genome, the taxonomy of the bacterium *Rhizobium* and the carbon and nitrogen metabolism of bacteria and their host plants. As of the end of 1997, the centre — which currently has 12 full professors and 14 assistant professors — had contributed 130 papers to international journals, with about 2,200 citations.

So far, however, these discoveries have not been accompanied by corresponding improvements in Mexican agriculture. Part of the problem, says the centre's director, Georgina Hernández, is slow overall progress in this area of research. "What people thought would be possible 15 years ago turned out not to be so easy," she says.

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the greenhouse, but there have been problems with their ecology, and their survival in the field."

But some plant biologists from other Mexican institutes think that the centre's scientists have been too consumed with striving for academic excellence to pay attention to applied research. "They had the philosophy that applied research is not good for science," says one. Another, who is disappointed that the centre has not done more to help farmers, expresses a similar view: "They are excellent scientists. They could do better if they would just focus their brilliant brains on applications."

Hernández, who became the centre's director two years ago, acknowledges that most of its founding scientists had little or no experience of applied research. But she insists that what others interpret as a lack of interest in applications was instead a reluctance to undertake applied projects that did not have a solid grounding in fundamental research.

Whatever the reason for past reluctance, Hernández has been improving the balance between basic and applied research by encouraging collaborations with agronomists and growers. For example, strains of *Rhizobium etli* that have been genetically engineered to fix more nitrogen are being tested as inoculants of different bean varieties grown in Mexico, in field trials organized jointly with INIFAP, the Ministry of Agriculture's research institute.

In another new project, scientists from the centre are studying free-living nitrogen-fixing bacteria that associate with non-leguminous plants, such as sugar cane. A group of sugar cane producers is funding work to identify varieties that can derive sufficient nitrogen from bacteria to grow with little or no applied fertilizer.



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spending figures are not yet available for the years after 1995, but there is no sign that any such industrial kick-start has occurred.

If optimists foresee a virtuous circle, pessimists recall the roller-coaster of past economic crises, together with the unpredictable swings of government policy. But there are reasons to hope that the future will be different. Although the economic crisis of 1994 is still taking its toll on R&D spending, the effects have been nothing like those of the

crisis of 1982–83, which led to an exodus of scientists that is still apparent today, as a 'lost generation' of researchers. Mexican politics is more democratic and less corrupt than it has ever been — conditions that bode well for the stability that science needs to flourish.

Ultimately, however, the success of the scientific enterprise in Mexico will depend on the ability of Mexican scientists — by words and deeds — to convince not just the government, but also the Mexican public, that scientific research is as important to the country's well-being as education, health or social justice. In the words of René Drucker-Colín, a neurophysiologist at UNAM, "the Argentinian Nobel prizewinner Bernardo Alberto Houssay said that Argentina was too poor to have the luxury of not investing in science. The same applies here."

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ven for those fortunate scientists in Latin America who manage to obtain adequate funding, have bright graduate students to work with and fast Internet links connecting them to the world of science, a major obstacle remains on the road to first-rate research: fast access to equipment and materials.

Scientists in all disciplines in most countries in the region complain about the time it takes to process major items of research equipment through customs. Often their problem is persuading every level of the customs bureaucracy that the item to be imported is duty free. Simply paying the duty is not usually an option, because funding agencies refuse to cover the cost of taxes that should not have been paid.

But it is biologists, who depend heavily on perishable reagents, including cultures, bacteria and tissue samples, who are most severely affected. Desperation often drives the region's life scientists — not to mention their colleagues at US or European universities, and even their family members on vacation — to hide materials in their luggage before making a trip south.

Supplies "always late"

The extent of the problem varies across Latin America, but its underlying effect is fairly uniform. Imported supplies are always late, and, if supplied locally, their prices are inflated to about twice US levels. Biologists learn to plan their work around the uncertain time delays. But their research institutions can make a major difference: many have specific offices dedicated to dealing with customs, and some have established offices in the United States. Institutions keep as strong an inventory of reagents as they can afford.

"You just have to plan in advance," says Igor Polikarpov, head of protein crystallography at Brazil's national synchrotron light source at Campinas. The progress that a particular reagent will make on the route through customs depends on the officer who deals with it, he says. Perishable enzymes can be destroyed by an unsympathetic inspection at customs, whereas chemicals such as acetones, which are used in cocaine processing, always attract unwanted attention.

Some other researchers in Brazil report that average delays for packages coming through customs from abroad have increased recently, after a period of improve-



ment. "What people are doing," says one of them, "is smuggling."

Franklin Rumjanek, head of biochemistry at the Federal University of Rio de Janeiro (FURJ), says he feels defrauded by the representatives of supply companies who bring reagents into the country and charge "at least twice" the price they would charge in the United States. Rumjanek does not predict any bureaucratic solution to the problem: the only way around it, he says, is for the reagents to be produced in Brazil.

George dos Reis, a biophysicist at FURJ, says that it can take six to nine months to order some supplies, and also complains about inflated prices of locally available reagents. "It has always been like that," he says. "It's a big limitation."

In Argentina, delays reported at customs are a little less severe. "We can get items out of customs in two or three days," says Carlos Frasch, director of the Institute of Biotechnology at the University of General San Martín. "Or you can purchase it through a representative in Argentina — but that is twice the price." In all, it can take "15 or 20 days at the most" to order and receive reagents, he says.

Ordering major equipment is, however, another matter. In Argentina, securing its exemption from import duties can be a huge task. "Big pieces of equipment can take a year," says Armando Parodi of the Campo-

mar Foundation in Buenos Aires, who recently waited all of 18 months for delivery of an incubator.

The two principal Chilean research universities have each established beachheads in the United States, to assist with the movement of materials. Scientists at the Catholic University often get colleagues in the United States to donate material to a company based in Miami, which then arranges fast delivery through a contract with the university.

The University of Chile, meanwhile, has established an office of its own in Washington, called University International Exchange, which although devoted chiefly to scientific exchange or collaboration, also helps some university scientists to receive donated supplies and equipment from the United States.

In Mexico, some scientists envisaged the situation improving after the country joined the North American Free Trade Association (NAFTA) in 1994. "We were all very happy about NAFTA and had high expectations," says Carlos Arias of the National Autonomous University's Institute of Biotechnology, in Cuernavaca. "But things haven't changed that much. Sometimes by the time items arrive, we forget what we wanted them for."

Office at airport

CONACYT, the Mexican research council, has an office at Mexico City airport to help expedite supplies, but some scientists are unaware of its existence. In addition to inflated prices and delays of weeks or even months for most imported reagents, Mexican scientists report particular problems obtaining chemicals whose movement is restricted by the US Drug Enforcement Agency.

Although most scientists in Latin America believe that problems with obtaining reagents are a significant hindrance, some of the more experienced ones say that these complaints are overblown. Ricardo Uauy, for example, director of the Institute of Nutrition and Food Technology (INTA) at the University of Chile, says that researchers can get what they need. Ricardo Brentani, director of the Ludwig Institute in São Paulo, bluntly rejects the assertion that materials supply is holding back Brazilian science: he suggests that some researchers use it as an excuse for bad performance.

Whatever the true extent of the problem, many different bureaucratic solutions have been proposed to deal with it. In Argentina, for example, it has been suggested that scientists simply pay duty on research materials and that customs redirects a lump sum of money back to the science agency. But scientists' best chance of alleviating the problem is to have competent, specialized staff in their institution or university to do the tiresome legwork needed to expedite materials through customs.

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Colin Macilwain

hichever way you look at it — by the reputation of its leading researchers abroad or the orderliness of its universities, by the amount its government spends on science or the number of papers its researchers publish each year in international journals — Chile's small scientific community is one of the more perfectly formed in Latin America.

According to figures from the Institute for Scientific Information (ISI), the Philadelphia-based institute that monitors scientific publishing trends, Chile produces more international papers per head of population than Argentina, and three times as many as Brazil or Mexico. Its government says that it spends 0.67 per cent of gross domestic product on research, far more than any other country in the region except Brazil, whose claimed expenditure is artificially inflated (see page A16). The main universities of Chile were not targeted for disruption by the military dictatorship of General Augusto Pinochet, nor have they been forced by democratic governments to absorb impossible numbers of undergraduates. And according to at least one well-informed observer in the United States, Chilean neurobiologists come as close to top international

standards as anyone else in Latin America.

For Chile's scientific elite in Santiago, however, the successes of the country's research base are less apparent than its failings. Perhaps it is the proximity of unfettered success — most were trained at the best research universities in Europe or the United States, and many still work with these universities — but they continue to see the cup as half empty.

For the past six years, the government of President Eduardo Frei has taken a novel approach to developing scientific excellence in the country. With the guidance of Claudio Teitelboim, a theoretical physicist of international repute who has served as his science adviser, Frei has sought to raise standards in Chilean science by concentrating resources on a few of the best scientists, regardless of their discipline or institution.

Most countries in Latin America have sought to mimic the advisory committees and other science policy structures of the developed world, even if they lack funds to implement them. But as a recent critique prepared by an invited group of Canadian experts confirmed, Chile has no national council of advisers on science and technology, and no clear national science policy.

"One often hears the complaint that there is no national policy for science, or that we need to coordinate our efforts," explains Teitelboim. "I don't really agree. There are too many policy makers involved in science worldwide — especially mid-level ones. Any grand science policy here in Chile would just be a collection of nice words."

Instead, Frei has sought to do what many scientists in any country say they most approve of — he has supported excellence, without strings. Forty "presidential chairs" have been awarded, and their occupants given around US\$100,000 a year each to support their research: a sum that probably brings them closer to US levels of research support than any other government scheme in Latin America.

Millennium Institutes

Teitelboim is now working with the World Bank to extend this approach to support a small number of so-called Millennium Institutes, which will receive up to \$2 million a year each to perform internationally competitive science (see *Nature* 396, 711; 1998).

Teitelboim has in his mind the analogy of a yawning gap — "an abyss" — that separates



researchers in his country from those at the leading edge of science. "There is no way to cross it gradually. If we move too slowly, we will not succeed. We need to jump to the other side." The extra something that will cross the divide is "a direct connection with the world elite in science. It is not enough to attend an occasional meeting. Researchers need to have a direct line to the heart of science in the world."

The millennium proposal has created intense excitement among groups of scientists, such as neurobiologists and astronomers, who think they are best-placed to lead such an experiment. It has also drawn criticism from those who favour a more broadly based approach. "I don't see it as a priority," says Jorge Allende, director of the Institute of Biomedical Sciences, a new institute which embraces much life sciences research at the University of Chile, the country's largest research university. Allende points out that Chile is producing only 50 PhDs a year in all disciplines, and has no trained researchers in vital new fields of science, such as genomics and bioinformatics. "Supporting more young people should be a higher priority," he insists.

The sparsity of support for graduate students is certainly a major problem. Mauricio Sarrazin, the civil engineer appointed by Frei to head Chile's principal science funding agency, the CONICYT, says that one of its main priorities is to increase

human resources in science and technology. "We've been able to increase our scholarships to about 350, but it's still too few," he says.

At the other end of the age spectrum, Chile's universities are full of too many elderly researchers. There is



Teitelboim: Chile has to cross "an abyss".



The Catholic University in Santiago: one of the best in Latin America.

no forced retirement, so many staff work on rather than retire on a meagre pension. For example, in the 12 university departments that have been brought under Allende's institute, the average age of the 350 faculty was 52, until the institute provided some retirement incentives and the money to hire 35 new staff.

Allende says that the reorganization of Chile's largest biomedical research centre is, like the French Revolution, guided by three words: excellence, renewal and integration. "The biomedical sciences have come to the point where there's no real separation between the disciplines," he says. Researchers have arrived from as far afield as Italy and Switzerland to provide renewal. At present, Allende has \$4 million in annual research funding to support 250 staff. "We obviously need to do better than that," he says.

Across Santiago at the University's Institute of Nutrition and Food Technology (INTA), another of the country's best life scientists, Ricardo Uauy, has been struggling with the same set of problems for almost ten years, since returning home from the University of Texas Southwestern Medical Center to head up the multidisciplinary institute.

"There's always an interplay with politics which makes trying to do science very difficult," says Uauy. With leadership of places such as INTA elected by faculty, "it is hard for people with high academic standards to survive," although his own example shows



Uauy: standards are hard to maintain.

that this is not impossible. INTA has set up an impressive array of collaborations with scientists in Europe and the United States, and has re-aligned itself away from malnutrition, which is no longer such an issue in modern Chile, to a new agenda of food

safety, disease prevention and optimal nutrition. "Incorporating change is a problem," says Uauy. "There's no accountability, and this institute could have kept going with malnutrition, even though the problem had gone away."

Like many of the more experienced hands in Latin American science, Uauy has seen plenty of genuine adversity in his time and is impatient with the suggestion that science in the region is being held back simply by a lack of resources. "We don't have everything we want but we have everything we need," he says. The challenge in developing countries is not bricks and mortar, he argues, but "the standard to which people work" — and the gap that separates that from the standard to which the same people would work, and indeed have worked, in Europe or the United



Renato Saavedra, a student at the Catholic University, operates a laser in the plasma physics lab.

States. "The really important change would be to have a good academic level at the university, at all levels." For now, he adds, too many people see the university simply as a place of employment.

Good reputation developed

This problem is less acute at the University of Chile's great rival, the Catholic University, a private institution that has developed a reputation as one of the best universities in Latin America. "This university is well organized, and very efficient in its use of resources," says Francisco Claro, its dean of postgraduate studies and research. Claro is a University of Oregon-trained physicist and the author of a recent book about science — *A la Sombra del Asombra* [*In the Shadow of Astonishment*] — the local popularity of which has surprised no one more than the author.

The university, which gets about \$12 million in research grants out of its total budget of \$100 million, may be the best in the country, but Claro says it cannot compete with US research schools. "It is a matter of available resources," he says, contrasting his budget with the 25 per cent of a far larger total university budget which Stanford University in California spends on research. "The cow is just a calf here, and we cannot milk a calf. I'd like my boss to declare that we are a research university. But he says that with \$12 million to spend, we can't compete with places such as Stanford."

If resources are indeed the question, astronomy is the one branch of Chilean science that has the answer. According to Hernán Quintana, head of astronomy at the Catholic University, Chile is set to obtain around 10 per cent of the viewing time on \$2

billion worth of international telescopes that will be built on the Andes by 2010. "In that sense astronomy is unique," Quintana says. "It is the only field of science in which Chile is able to be in the world's top ten." Quintana and José Maza, his counterpart at the University of Chile, have contrasting views on how the field should develop (see page A13), but they plan to bid jointly to host a Millennium Institute.

Teitelboim believes that a few such islands of excellence should be established to serve as examples before the rest of Chile's research system is reformed. "It is better to have a unit that is different set up as a prototype," he says. "The next step should be a major overhaul of the system as a whole."

But many Chilean scientists, faced with the obvious day-to-day problems of teaching and conducting research there, believe that such an overhaul is long overdue. José Maza says that the university system is 'chaotic' with a budgetary system that provides them with no incentive to do research.

Both the University of Chile and the Catholic University used to fund almost all of their research themselves, and CONICYT, which was founded in 1965 as a national research council to give advice to the government, started giving research grants only in 1982. Now it supports almost 1,000 scientists at an average level of about \$25,000 a year each — not too bad by Latin American standards, but not enough for the internationally competitive research that most of them

aspire to perform.



Claro: "we cannot milk a calf".

The fairness and consistency with which grants are allocated attracts criticism from leading scientists. "The process allocates resources with some degree of priority, but mostly to try to keep everybody happy," says Uauy. Some wish that Teitelboim, instead of just

advising Frei on science policy, had taken the presidency of CONICYT and tackled the business of reforming it, instead.

Teitelboim himself, after returning to Chile in 1984 from exile (his father was secretary of the Chilean communist party) to eventually gain a position of influence with the government, professes disappointment with the progress that science has made under President Frei. "We have achieved very little really," says Teitelboim, reflecting on the past six years. "We are proud of the presidential chairs." He continues, only half in jest: "I'd have hoped to see the astronomers agree on something. I'd have liked to have a few Millennium Institutes running by now — and some indication that talented young people were coming home to work in them."

Roland Pease

Many astronomers regard Chile as the best place on Earth for astronomy. A stroll at night outside the dome at the Cerro Tololo Inter-American Observatory (CTIO) near La Serena in northern Chile reveals why. The sky is crystal clear, and so still that stable images of stars are a near certainty. Then there is the weather. During the summer months, from January to March, cloudless skies are almost guaranteed — a priceless asset for a profession that is at the mercy of the elements.

Little wonder, then, that the world of astronomy has beaten a path to Chile's door: up to 800 foreign astronomers visit each year. Besides the CTIO, with its seven telescopes, there are the telescopes at Las Campanas, run by the Carnegie Institution of Washington, and the European Southern Observatory (ESO) at La Silla, on the southern edge of the Atacama desert. And more are being built.

The three main observatories have been running since the early 1960s, and Chile had a history of involvement in astronomy long before then. A national observatory was established at Cerro Calán on the outskirts of Santiago in 1852, fulfilling the usual maritime and timekeeping functions of observatories at that time.

Foreign involvement goes back a long way too: US astronomers came to Santiago as early as 1847 and a southern-skies outpost was established by California's Lick Observatory in 1902. For many years, this was the largest telescope in the Southern Hemisphere. It was inherited by the University of Chile when the Californians left, but closed in the 1940s.

The rebirth of astronomy at the end of the 1950s was very much the result of efforts by local astronomers, although the money and technology came from abroad. It was the director of Chile's national observatory, Federico Rutland, who, learning of US interest in southern astronomy, persuaded Gerard Kuiper from the University of Chicago to survey the coastal mountains of northern Chile for suitable sites for a new observatory.

The CTIO was the outcome of that search: "one of the best observatories in the world" says Nick Suntzeff, a staff astronomer there. Its large four-metre telescope made a key contribution to the recent discovery of accelerating expansion over the history of the Universe (Garnovich *et al. Astrophys. J.* 493, L53–L57; 1998).

From the outset, Chile won access to 10

per cent of the available time at CTIO for its own astronomers, although access at ESO has been agreed only from this year.

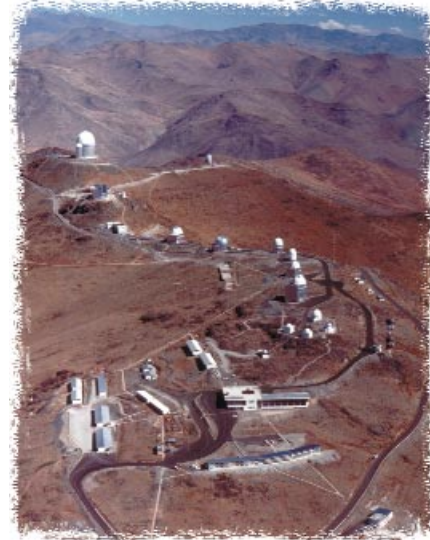
University held "monopoly"

Hernán Quintana, head of astronomy at the Catholic University in Santiago, says that lack of access held back Chilean astronomy — but claims that an even more significant problem was the effective monopoly held on the discipline by the University of Chile, the country's main public university, after it absorbed the national observatory in 1964.

The Catholic University is now challenging that monopoly, and Quintana believes that a greater intake of undergraduate and graduate students in astronomy will enable the country to develop excellence in the discipline. (In common with most senior Chilean scientists in all disciplines, Quintana himself was trained outside Chile.)

But José Maza, head of astronomy at the University of Chile, counters that training more students will not necessarily lead to better science. He remains unconvinced that funded positions will become available for many more astronomers than the 25 or so which Chile has at the moment.

Quintana also accuses the government of indifference. Chile's involvement in the new Gemini telescopes — giant eight-metre instruments being placed in Hawaii and near La Serena — was nearly forfeited by the treasury's failure to pay the US\$9 million subscription until almost the day of the



The European Southern Observatory offered no time to Chilean astronomers until this year.



The CTIO has helped enable breakthroughs in our understanding of the Universe.

deadline, in 1997, he says. Astronomers were not involved in the negotiations, and nor was CONICYT, the main science funding agency.

Help for Chilean astronomy is coming from outside. The Andes Foundation, a trust fund based in New York that puts seed money into Brazil, Argentina and Chile, regards astronomy as the key Chilean science. And the Catholic University and the University of Chile have established links with Princeton and Yale universities, respectively, to collaborate on research and graduate training.

The project manager for Gemini's southern site, Oscar Riveros, who is also CONICYT's coordinator for astronomy, sees it as an opportunity to build up an indigenous astronomy infrastructure. The project's communications, for example, are being developed by a consortium of Chilean universities and the telephone company CTC. Four Chilean engineers have spent the past year working at Gemini's northern site, in Hawaii, and another will be visiting Britain to learn about the optical-coating paint for Gemini South's mirror.

The tables have turned since the days when Chile made no demands for scientific involvement in the ESO. If anything, Riveros says, it has been too successful in negotiating with its guests. Chile now has access to 350–400 nights of observing time a year on its soil — enough to keep over a hundred astronomers busy. And if Riveros thinks it is a challenge to find that number, Quintana is more optimistic. "Because of the big observatories in Chile, we're coming much more into the public eye," he says. "People realize that there are going to be jobs in astronomy."

The result is some enthusiasm for astronomy among young Chileans. Chile has a rigorous national schools testing system, in which every high school graduate receives a score of up to 815 points. The best student in the country last year, according to Francisco Claro, dean of research at the Catholic University, scored 814 points, and has chosen to join the university's new undergraduate astronomy programme.

Colin Macilwain

After a hectic day fighting to save his country from currency contagion — it's Monday on the week after the Brazilian réal collapsed, and speculators have the Argentinian peso in their sights — the Argentinian chef de cabinet, Jorge Rodríguez, is relaxed and relieved to be talking science, in spite of everything. "Most of the people in the scientific field aren't fond of our [Peronist] tradition," he says wistfully. "We don't like to talk: we prefer to do things."

Rodríguez, who trained as a plant geneticist at the University of Nebraska, is right about the intuitive hostility of many scientists and other intellectuals towards both the party and the government of President Carlos Menem. But as that government comes to an end — Menem will probably stand down, and his party is widely tipped to lose this autumn's presidential elections — many scientists now accept that its attempts to reform Argentina's science and technology policy have been worthwhile, if belated.

Neglect ended in 1996

Menem neglected research for the first term of his presidency, but since 1996 a fairly bold programme has been underway to renew Argentina's considerable scientific tradition. The establishment of a specific national science and technology plan, a science cabinet chaired by Rodríguez, and a new National Agency for the Promotion of Science and Technology (known as 'the Agency') have been widely maligned by a scientific community that still feels woefully under-resourced. But as the Agency, which has been funded largely by a loan from the Inter-American Development Bank (see *Nature* 391, 525; 1997), gathers steam and reforms are implemented, resistance is giving way to a recognition that things are finally beginning to improve.

The government has sought new ways to promote science through the Agency, by pro-



viding incentives for collaboration with industry, and through agreements with foreign governments, Rodríguez says. It will support basic research "in the things that we do well," he says. He cites biotechnology as an example of a field in which Argentina has the potential to expand, building on the tradition established by the three Argentinian biochemists who have won the Nobel prize — Bernardo Alberto Houssay (medicine, 1947), Luis Leloir (chemistry, 1970) and César Milstein (medicine, 1984).

But the young biologists who aspire to replicate the Nobel successes work a long way from Rodríguez's magnificent office in Government House, and see little evidence that his government values their endeavours. "It is very difficult to make a postdoctoral career in Argentina," says Diego Comerci, a graduate student at the Institute of Biotechnology at the National University of General San Martín in Buenos Aires (see box).

"There's money to train scientists, but then no money to support them," adds Guido Pollevick, a post-doctoral researcher at the same institute. Young scientists there are critical of both the government and of the National Council for Science and Technology (CONICET), the research council which employs most Argentinian research sci-

tists at 147 research centres across the country, and which one of them brands "sclerotic".

Asked what he is doing for these people, Rodríguez responds brusquely that they "should know that there are opportunities to work in the private sector, in pharmaceuticals or mining." It's an answer worthy of Carlos Del Bello, the government's science and technology minister, whose extensive reforms and direct manner has made him many enemies in the community. Scientists feared that the Agency was designed by Del Bello to place science under direct political control, and that it would expand only at the expense of the CONICET. Now that the CONICET has received two years of reasonable budgets, however, and the Agency is operational and distributing grants, its legitimacy has increased.

"Policy has improved over the past couple of years, with the Agency," says Armando Parodi, a Howard Hughes scholar and glyco-biologist at the Campomar Foundation in Buenos Aires. But he still argues that the government is not supporting basic science, and that neither CONICET nor the Agency is sufficiently independent from political control.

Some scientists continue to distrust the Agency and Del Bello, its architect. "He doesn't believe in science, he is not an intellectual, and he's jeopardizing the future of the country," says Enrico Stefani, a biophysicist at the University of California at Los Angeles, who spent a turbulent year in Buenos Aires as president of the CONICET.

Stefani left last year after clashing with the government over the appointment of staff at a scientific institute that was being established in President Menem's home town. He now fires at the government from a distance, hoping to return from exile if a new government is elected. "Science in Argentina is non-competitive because the administration is corrupt," he says flatly. "What's tragic is that there is a fantastic young generation there, and no way for them to develop."

Grants at international levels

But the Agency continues to make progress. In this, its second year of operation, it has raised the ceiling on the grants it will deliver from US\$25,000 to US\$50,000 a year, for three years. "We think that \$50,000, on top of salary, is a pretty good level," says Mario Mariscotti, the physicist who directs the Agency. "We believe it will bring us up to international standards." He expects to make about 600 such awards, on top of the 700 made last year. "We have the feeling that top quality is limited to about 1,500 groups," says Mariscotti. "I'm aware that some people feel that the Agency has taken something away from CONICET, although this isn't really true. I think there's a 'silent majority' that appreciate what the Agency is doing."

CONICET itself, which spends three-



Argentina's three Nobel prizewinners — Houssay, Milstein and Leloir — stand as testament to its traditional strength in biochemistry.



entian research sci-



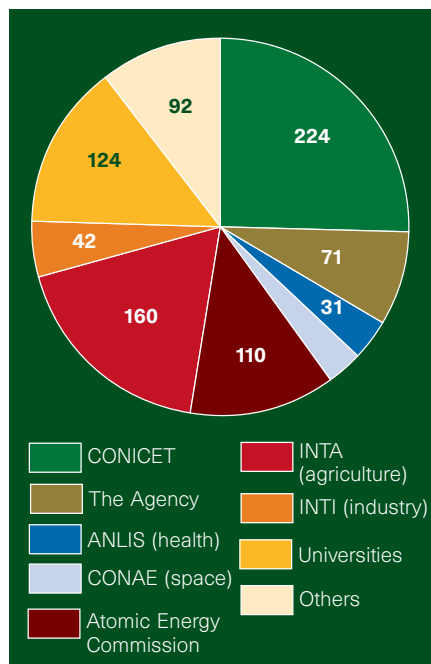
The Campomar Foundation in Buenos Aires.

quarters of its \$220 million budget on researchers' salaries, has been able to employ 600 new researchers this year — ending a prolonged freeze on hiring — and is undertaking a review of its institutes. Afterwards, says Del Bello, “we will decide how many will stay and how many will close, or be merged.” He predicts that four-fifths of the scientific ones will stay open, but that their management is likely to change, with more non-scientists involved in management. Del Bello is characteristically scathing about the track record of the CONICET under the management of scientists: “They were in charge before, so why was there no evaluation of the institutes, or of the researchers?”

Argentina has also encouraged the growth of newer technology-orientated universities, such as the National University of General San Martín. The government, and many researchers, view the old universities as over-bureaucratic, distant from industry and commerce and impossible to reform.

Inequalities in reforms

Large components of Argentina's research infrastructure remain untouched by the reforms, however. The National Atomic Energy Commission, whose \$100 million budget represents about 10 per cent of the nation's investment in research and development, appears to be veering out of control after Del Bello tried and failed to turn it into a



Argentinian government spending (in US\$ million) on science and technology, 1998.

science agency. The commission has cut itself loose from the science ministry and re-committed itself to the quest for viable fission power, which retains strong Peronist support.

“Del Bello had some peculiar ideas,” says Dan Beninson, president of the commission. “He wanted us to be a second CONICET.” Beninson has different plans. “I came here to re-nuclearize the commission,” he declares robustly, suggesting that it will earn its keep by developing small, intrinsically safe fission-power reactors for export. “We see a substantial market that can be developed in Africa,” he says.

“They are quite mad, but they have power,” says Mario Albornoz, director of the Institute for the Study of Science and Tech-

nology at the University of Quilmes in Buenos Aires, of the people in charge of the government's nuclear policy.

Albornoz has prepared a science policy document for the alliance of parties that hopes to defeat the Peronists at the next election, and is tipped to head the science ministry in that event. The alliance, he says, plans to develop a much stronger industrial policy for Argentina, and, eventually, to double spending on research and development, to 1 per cent of gross domestic product (GDP).

But Albornoz supports the Agency and the other reforms of science policy which Del Bello has undertaken, and was even involved in recent meetings with the Inter-American Development Bank to discuss future funding for the Agency. Echoing Del Bello, Albornoz accuses scientists of obstructing necessary reform. “The research system here is obsolete,” he says. “Many researchers have no funds or equipment. But leaders of the scientific community prefer that to a modern policy, because such a policy would take away their powers.”

This language of power struggle often permeates discussions of Argentinian science policy, reflecting the violations suffered by the academic community under the country's military dictatorship, which ended in 1983. As Argentinians freely point out, the country hasn't come to terms with the dictatorship's legacy; punishment of the crimes committed under its name, rather than economic or social issues, will be the central issue in this autumn's elections. In such a climate, scientists and other academics value their intellectual independence above all else, and attempts by the Peronist government or foreign banks to steer science and technology policy have been treated with suspicion. This atmosphere of mutual mistrust may have to lift before Argentina can take the place in world science to which it aspires.

Biotechnology institute leans heavily on foreign funding

The space-age feel of the new Institute of Biotechnology at the National University of General San Martín in Buenos Aires is borne more of necessity than design — the former army hut was converted into a well equipped research laboratory in 1996. Conversions of another two buildings are underway, and institute director Carlos

Frasch hopes that their completion will cement



its reputation as one of the most dynamic places to do molecular biology in South America.

Sixty researchers and students work at the Institute. Frasn left the University of Buenos Aires to come here, citing the freedom offered to the institute by the new university of which it is part. He has since obtained an international scholarship from the Howard Hughes Medical Institute (HHMI) for his own work, and the institute also attracts support from the World Health Organization (WHO), the World Bank and the United Nations Development Programme. “We get 70 per cent of our support from abroad, and the rest from Argentina,” says Frasn. But staff salaries are paid by the university and by

CONICET, the national research council.

The aim of the institute is to do basic research in molecular biology, applied research in biotechnology and teaching at the university. Around 20 papers are published each year from the institute, mostly in international journals.

Five of the six research groups are working on basic science, including projects on the molecular biology of parasites, and part of a WHO programme to sequence the genome of *Trypanosoma cruzi*, the agent that carries Chagas' disease. A biotechnology group at the institute is exploring the genetic modification of potatoes and other vegetables with the aim of altering their starch content.

Colin Macilwain

One of the least welcome tasks facing researchers at the Federal University of Rio de Janeiro — the second largest research university in Brazil — is to review grant applications from their colleagues 300 miles inland in São Paulo. “They ask for money for air-conditioning for cows and sheep [used in agricultural research],” says one of them, glancing around his sweltering laboratory. “Round here, we’re lucky if we have air-conditioning for people.”

The long-standing dichotomy between the condition of scientists in industrial São Paulo and those in the rest of Brazil has only been exacerbated by the country’s latest economic crisis. The Foundation for the Support of Research of the State of São Paulo (FAPESP), the state funding agency for science, will continue this year to invest in world-class equipment while supporting a sizeable scientific community at developed-world levels. The rest of the country, meanwhile, is witnessing the sharp retrenchment of a system that was already manifestly incapable of supporting the large and talented complement of qualified scientists that Brazil’s universities have produced over the past 20 years.

Scientific expansion in São Paulo

FAPESP spent around 320 million réals last year on grants and equipment. (The Brazilian réal was worth nearly US\$1 until January; since then, its value has fallen by almost half.) Two-thirds of this sum came from a state government that is obliged, under its constitution, to send 1 per cent of tax revenues to the research agency. The remaining funds came from investment income on the endowment that FAPESP has built up during years when it spent less than the state government provided — a valuable shelter from the economic storm now wracking Brazil.

The 1.4-GeV national synchrotron light source, which was completed at Campinas in São Paulo state in 1997, is operated by the federal government but has obtained equipment from FAPESP and reflects the relative scientific opulence of its home state. Scientists there have ready access to international journals and instant Internet access through a FAPESP backbone.

Igor Polikarpov, head of protein crystallography at the centre, exudes confidence about the impact that the R\$70 million, state-of-the-art facility can have on science

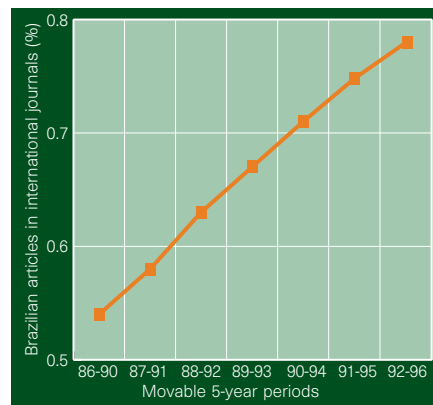
in the region. Polikarpov has trawled Argentina and Brazil encouraging biologists to use the new facility to solve molecular structures. He believes that availability of the light source, together with FAPESP’s ambitious project to sequence the genome of the microbe *Xylella fastidiosa* (see box), can revolutionize molecular biology in the country.

The laboratory’s operating budget has been stable, at around R\$12 million a year, since 1996. But despite its strong concentration on materials science, it has obtained little support from industry. “Brazilian industry doesn’t buy research in Brazil, they get it from abroad,” says Ricardo Rodrigues, associate director of the light source, sounding a refrain common to many Brazilian academics.

“We hope the situation will change,” says laboratory director Cylon Gonçalves da Silva, noting that Brazil cannot expect to import all of its technology needs. “This whole laboratory is a bet that things here will move in the right direction.”

At the University of São Paulo, the leading research university in Brazil, the same bet has been rolling since 1934. It was then that a group of refugees arrived from Europe’s turmoil to help found the university on the German model, around a cluster of existing colleges. “They brought a culture in their pockets,” says Hernan Chaimovich, dean of research at the university.

The university has a budget of R\$800 million, 25,000 graduate students, several highly rated departments and a publishing record (2,600 papers in international journals last year) that compares favourably with a middle-ranking research university in the United States. Yet Chaimovich acknowl-



Brazil’s portion of papers published in international journals has expanded steadily.



edges that the global impact of the university does not match that of such a US university, and admits that the bureaucratic structure of the university is an impediment to achieving such an impact.

“Out of 200 departments here, we have 10 that are clearly of international class, and every one of them has had problems with the university,” he says. Chaimovich contends that “human contact and atmosphere” are more important than resources in creating an environment for world-class research, and plans to develop “research nuclei” at the university, where researchers from different disciplines will operate outside the constraints of existing departments.

Links forged with industry

The university has made some progress in developing its ties with industry. For example, Marcelo Zuffo, a young computer scientist, helps to run a parallel-processing unit at the electrical engineering department, which has attracted millions of dollars of support from Motorola. The centre is developing inexpensive, massively parallel supercomputers which Elebra, a Brazilian equipment manufacturer, hopes to sell to cable TV operators and other potential users of commodity supercomputers. “We’re looking for the right model,” says Zuffo of his centre, “light and flexible, with a high turnover of people, strong links to the university, and a managing board on which our industrial partners are represented.”

Brazil’s industrial base has been subjected to a painful transformation over the past decade: the publicly owned corporations that were supposed to drive modernization have been privatized and dismantled, while foreign corporations have poured investment into plants that assemble computers and cars using technology from overseas.

But where some Brazilian scientists see only the ruins of the old industrial base, Zuffo senses opportunity. “Brazil will soon be the fourth-largest car maker in the world,”

he points out. "There will be 200 chips in every car. Our feeling is that there is a huge market for our ideas — when we have ideas we go to industrial partners, and they fund us."

If Zuffo's slick optimism resonates with the modern bustle of São Paulo, it jars with the day-to-day reality facing the rest of the country. Rio de Janeiro is by no means the poorest province in Brazil, but the conditions endured by researchers at the Federal University of Rio de Janeiro (FURJ) reflect the general problems afflicting science there.

University's budget goes on salaries

The university spends about 95 per cent of its R\$500 million budget on salaries, leaving little for the amenities necessary to undertake research. There are exceptions — the modern and well equipped engineering school, for example, which receives substantial support from industry through a private foundation set up for the purpose.

Internet access at the university is, however, painfully slow, and the library stopped paying for all journals last summer when a grant from the federal government to buy them was cut. The government of Brazilian President Fernando Henrique Cardoso has recently appointed a new university president, but he was not elected by faculty staff and has been subject to considerable animosity.

The state of Rio de Janeiro has sought to outmatch São Paulo with a constitutional requirement to spend not 1 but 2 per cent of tax revenues on science and technology, but the requirement is not adhered to. "It's not as if anyone is going to impeach a state government just because they don't abide by the law," as Fernando Perez, scientific director of FAPESP, puts it. Last year, the state of Rio de Janeiro spent just 0.1 per cent of revenue — R\$9 million — on science.

This dismal performance could shortly improve, however. The new president of the state signed a pledge to reach the target of 2 per cent and appointed Wanderly de Souza, a popular biophysicist from the federal university, as his science secretary. "Our idea is to get to 2 per cent by the end of this government [in four years time]," says de Souza. "By the middle of the year, I'll know if things are going as well as planned."

This year the Rio de Janeiro science agency, FAPERJ, has a budget of R\$48 million and has at least received its first two monthly instalments of R\$4 million each. Beyond that, scientists are not overly optimistic. "The last administration said



Scientists at Brazil's national synchrotron light source use its beamlines for chemistry, biology, physics and materials science.

they'd do this in 1995, but it didn't happen," says Leopoldo de Meis, a prominent biochemist at the university.

But researchers at FURJ are proud of what they achieve under adverse circumstances. George dos Reis, another biophysicist at the university, points out that the university produces about half as much good science as the University of São Paulo with far less support from the state government. "It's very difficult, but I think we are keeping up with international standards," he says. "We're doing a good job in a terrible situation," says plant molecular biologist Paulo Ferreira.

Sharp realignment

The economic transition of the country over the past decade is now forcing an equally sharp realignment of Brazilian science policy. The country had spent 25 years planning for self-sufficient industrial development, underpinned by a large group of scientists and engineers trained in the country's universities, or abroad (Brazilians usually return after studying overseas). This protectionist development strategy is now regarded as a failure — Brazil has privatized the industrial corporations that were at its core and opened itself up to multinational corporations who import technology.

In this brave new world, the role of science, technology and the universities is less clear. "In the early 1990s, the crisis became apparent," says Carlos Bresser, the University of Chicago-trained economist who was

named minister of science and technology in the government that took office in January, after President Cardoso's re-election. "Just spending money on science and technology was not solving our problems." The government sees the remoteness of academia from industry as a fundamental problem, although many academics deny culpability. "Innovative industry, if it ever existed, is disappearing," says Sérgio Ferreira, president of the Brazilian Society for the Advancement of Science. "The budget for science has come to a halt, as if it was something that was not necessary for Brazil."

Bresser is an accomplished reformer, whose arrival was viewed with some trepidation by Brazilian scientists. At a recent meeting of scientists supported by the Howard Hughes Medical Institute (HHMI) at Rio de Janeiro in January, Bresser expressed concern about over-supply of scientists and seemed unconvinced by their pleas for more resources. "We tend to import equipment that is never used," he said in response to one such complaint. "I hope we'll provide equipment for scientists who know how to use it."

Scientists are frustrated by government figures that put Brazil's annual spending on research and development at US\$5.5 billion (*Interamerican Science & Technology Indicators* 1997) while they struggle to maintain the meagre federal government programmes that support scholarships and basic research. As another Sérgio Ferreira, a Howard Hughes scholar at FURJ, told Bresser, "In Brasília you talk about billions of dollars, but at the other end we're lucky if we get cents!"

Bresser wants science to move closer to

Brazil's own needs. "We need to carry out research that is relevant to society," he says. "We should develop solutions that are relevant to the weather, or to the soil — things that the French and the Americans aren't doing for us."

However, his first move has been to embark on a reorganization of the Ministry of Science and Technology, disposing of the long-standing rivalry between the ministry itself and its semi-autonomous research council, the National Council for Scientific and Technological Development (CNPq), by merging the two and naming himself as president of the latter. The move alarmed scientists, who were not consulted (see *Nature* 397, 93; 1999). "There are certain kinds of changes which you do at the beginning, or not at all," explains Bresser.

He has asked Fernando Reinach, a biochemist and Howard Hughes scholar at the University of São Paulo, to execute the reorganization. Reinach says that the change will promote the vice-presidents of CNPq to the status and salary of under-secretaries in the government, enabling it to attract top scientists to come to Brasília for a few years and run the ministry's programmes.

The idea is to merge the scientific credibility of CNPq with the financial strength of the ministry, and create a more effective mechanism for supporting research and graduate education in Brazil. The country already has more scientists than it is able to support, and Bresser questions the CNPq's provision of so many student fellowships, especially at the masters level.

Instead, the ministry will try to muster its resources to support the best science through mechanisms such as the programme for national excellence in science (Pronex), which was started in 1996 and currently supports 208 multidisciplinary groups. Moyses Nussenzeig, a physicist at FURJ who developed the Pronex concept, says that the programme has attracted only about R\$40 million a year in funding, compared with the R\$250 million originally envisaged. "The way these projects are chosen is significantly better than any other process in Brazil," says Nussenzeig, who fears that the programme will be "destroyed" if support for it is cut any further.

Experts doubt statistics

The true status of science funding in Brazil was difficult to ascertain even before January's currency crisis, according to the experts who compile the statistics. Although the government says that national investment in research and development (R&D) has been stable at around R\$5 billion a year, one science studies group at the FURJ argues that it has plummeted by half since 1996. "There's a stable amount of money from the government," states Bresser, adding that industrial R&D has grown.

Critics say that industry claims tax

Genomics could safeguard citrus crop

As well as producing half of Brazil's science, São Paulo state produces around one-third of the world's oranges, so it seems only natural that the state's scientific leadership is seeking to jump-start its presence in molecular genetics through an ambitious programme to sequence the full genome of a bacterium that endangers citrus crops.

FAPESP, the state's science funding agency, decided two years ago that a special project was needed to boost genetics in the region. Today, 30 research groups across the state are close to completing the full, 2.1-megabase genome sequence of *Xylella fastidiosa*, a microbe that poses a significant threat to the region's citrus crop by causing citrus variegated chlorosis, a disease that blocks the circulation of nutrients in orange trees.

"It's the first project of its type to be done outside the United States, Europe or Japan," boasts Fernando Perez, FAPESP's scientific director. By obtaining the sequence of an organism whose biology has scarcely been studied, and then trying to establish gene functions and the workings of the disease, the project team hopes to catapult itself to the forefront of genetics.

Brazilian citrus growers have contributed US\$500,000 towards the US\$10 million project, emphasizing its potential relevance to their business.

"There was absolutely no biological information [about *Xylella*]," says Andrew Simpson of the Ludwig Institute in São Paulo, which together with two experienced groups at the University of São Paulo and Unicamp is coordinating the activities of all the different sequencing groups. "We think that this is a viable way to approach biological problems, and I don't think it has ever been done before."

refunds on non-existent research work, grossly distorting the figures. Also, agencies often spend less than the amount budgeted. "Money for grants is being reduced by a lot," says Jacqueline Leta, an expert in research statistics at FURJ. "No-one knows how much they invest in science and they are always confusing us [with more statistics]," she says.

The status of science in Brazilian society is also subject to dispute. "Most of the people have a very negative view of science," says de Meis at FURJ. Even when elites vow support for science, he says, "there's a gap between what they say and what they actually do. To fill the gap, administrative solutions are proposed." But Nussenzeig, an equally seasoned observer, contends that the country's population loves science and technology.

The fact that many Brazilian states have a constitutional provision allocating money to



The orange trees of São Paulo could be protected against citrus variegated chlorosis.

FAPESP wanted to get involved in genomics, Simpson explains, but decided against issuing a normal call for proposals from individuals, or setting up a centre — "we'd still be arguing about where to put it" — in favour of doing one, state-wide project. Observers of the project say that it has brought the best out of its participants — especially those who were previously isolated or underemployed — as well as attracting widespread public attention. The project has been noted in the international scientific and financial press, and will shortly be the subject of a four-part science documentary to be shown on São Paulo TV.

Perez says that FAPESP has now committed US\$35–40 million to genomics research and is looking beyond the sequencing of *X. fastidiosa*, towards projects that will sequence *Xanthomas campestris* — another bacterium that infects orange trees — and obtain cDNA sequences for sugar cane. But it is the functional genomics work following the sequencing that most excites Brazilian biologists.

science and technology — a provision that would be unthinkable in the United States, for example — itself speaks volumes to the faith that this nation has placed in science as a key to its progress. So does the impressive campus of the University of São Paulo, and the way in which even the military government chose, before its demise in 1985, to invest in an ambitious space programme (see page A19) and in graduate education. Despite the inconsistencies of policy and the chasm separating São Paulo state from the rest of the country, a broad-based scientific community continues to build up strength. "Brazil has been very dogged and persistent in supporting science through good times and bad," says Andrew Simpson, an English-born cancer geneticist at the Ludwig Institute in São Paulo. It can only be a matter of time before this investment bears fruit.

Tony Reichhardt

This year, if schedules hold, Brazil will finally realize its 20-year ambition to join the first rank of spacefaring nations. The agenda for 1999 has all the ingredients of a mature space programme, from the debut of a new Brazilian rocket to the selection of astronauts to fly on the international space station.

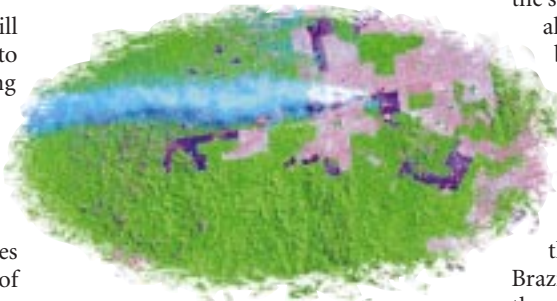
Although the space programme dates back to the 1960s, it was the 1979 approval of the so-called Brazilian Complete Space Mission that set Brazil on the road to self-sufficiency. The goal of this plan has been to develop the independent means to build and launch satellites, and Brazil has invested more than a billion dollars to that end.

This year the plan comes to fruition. The new VLS rocket, modest in size but 100 per cent Brazilian, should make its debut after a failed attempt to reach orbit in 1997. The first of two China-Brazil Earth Resource Satellites (CBERS) will be launched in July on a Chinese rocket. Brazil paid for 30 per cent of the satellite's US\$100 million cost and built one of its three cameras. The country hopes to reduce its dependence on US Landsat and French SPOT images, and also to obtain more frequent pictures of the Amazon region.

Largely owing to the vastness of its territory, remote sensing remains "very important for this country," says Luiz Bevilacqua, a professor of mechanical engineering at the Federal University of Rio de Janeiro, who represents the scientific community on an advisory committee to the Brazilian space agency. Moreover, the government seems to recognize that importance. Several years ago, President Fernando Henrique Cardoso ordered the National Space Research Institute (INPE), the lead agency for space science and applications, to improve the timeliness of space data on Amazonian deforestation. Now, says Thelma Krug, INPE's head of Earth observation, Brazil has "the largest programme in the world" for monitoring forests from space.

INPE hopes to launch the first of a pair of small, \$30 million Earth-observation satellites within the next two years. The satellites, dubbed SSR, will be placed in an equatorial orbit tailored to observing Brazil and other tropical nations.

Historically INPE, which receives about half of Brazil's annual budget of \$200 million for space activities, has also been the nation's lead centre for interpreting remote-sensing images. The institute used to be reluctant to



Satellite images, such as this one from Landsat, enable Brazil to keep track of forest burning.

share data with outside researchers, but the situation is improving. A private industry is slowly developing in remote-sensing analysis, particularly for agricultural applications. And Brazilian scientists have been striking their own relationships with foreign space agencies, independent of INPE. Roberto Calheiros, an atmospheric scientist at São Paulo State University, is scientific manager for a humidity sounder instrument scheduled to fly on NASA's PM-1 satellite.

A key question, however, is how much of a space programme Brazil can afford. In the early 1990s, when INPE's budget was in decline, institute director Marcio Barbosa made a choice to cut back on space science in order to fund higher-priority projects. Bevilacqua believes Barbosa "did the right thing" at the time. But the agency has accomplished little in space-based astronomy or planetary science as a result.

But that may change with the launch of Brazil's first science microsatellite, SACI-1, on the same Chinese rocket carrying the CBERS remote-sensing satellite in July. On board will be four small experiments focused on space physics. Because of recent declines in the size and cost of satellites, SACI-1 will cost INPE less than \$5 million.

The Brazilian-made VLS rocket will be launched this year.



The most recent addition to Brazil's space portfolio is microgravity research. Five experiments have already flown on the US space shuttle, and a research community is "growing rapidly" to take advantage of the country's new role in the international space station, says Bevilacqua.

The Brazilian government has pledged about \$150 million to become a partner in the station. The first Brazilian astronaut has already been named, and another will be chosen this year. Among the country's contributions will be a high-optical-quality window for Earth observation, which can be used to test instruments that would later be fitted on remote-sensing satellites.

Reactions to Brazil's participation in the project have been mixed among Brazilian scientists. Whereas some see it as a threat, others say the commitment of funds is relatively small. Most, however, agree that it is too early to say whether the new focus on astronauts and microgravity research will divert funds away from other parts of the space programme.

The threat of budget cuts is much on the mind of Brazil's space scientists. José Monserrat, editor of the *Journal of Science*, which is published by the Brazilian Society for the Advancement of Science, complains that "we have no clear priorities" in space, and that each project is left to fight for its own interests in a time of cutbacks. Money is scarce not only because of the reeling national economy, but also because funds appropriated by the government to INPE are often siphoned off for some other purpose before they reach the institute. The INPE budget, claims Monserrat, is a "fantasy," a charge that Bevilacqua backs. Brazilian scientists in all fields, not just space research, are angry that they are "not getting what's written in the contract," he says. He also worries that the agency is "not attracting good young scientists," because it cannot pay competitive salaries.

Despite these problems, most scientists inside and outside INPE believe that the programme will not only survive, but move forward. According to Calheiros, the government and the Brazilian people have come to understand the value of the space programme, not just for Earth observation but for its ability to spur technology development in Brazil.

Andrea Kauffmann-Zeh

The people of the Amazon basin are among the poorest of South America, but the region's rainforests are home to the richest diversity of life in the world. The potential of that wealth for the region was recognized implicitly for the first time in 1992, when representatives of 150 nations gathered in Rio de Janeiro to sign the Convention on Biological Diversity. But seven years later, the region is still struggling to tap any of that natural wealth, or even to plan for its future exploitation.

The convention redefined biodiversity as the "common heritage of humankind" and gave individual nations sovereign rights to it. Although it has not been ratified by the United States, the largest likely importer of biodiversity, the large pharmaceutical corporations are trying to work within its terms. But the Amazonian nations have made little progress in exercising their rights under the agreement. Instead, the use of the region's biodiversity by forest inhabitants, scientists and industrial groups remains a major source of controversy. Bioprospecting partnerships with foreign corporations raise even stronger feelings.

Supporters of the convention remain optimistic about its implementation, however. Roberto Cavalcanti, president of the Brazilian arm of the global conservation group Conservation International, and an ornithologist at the Federal University of Rio de Janeiro, says that bioprospecting — if done properly — will help to develop local scientific capacity, preserve and document indigenous knowledge, and provide incentives for conservation. "It could help attach an economical value to preserving Amazonian biodiversity," he says.

Walter Reid, a fellow at the Washington-based World Resources Institute (WRI), believes it is still too early to say whether bioprospecting will become economically significant. "The chance of finding potentially useful compounds is low, and developing a marketable drug is time-consuming," he says. "Some advocate up-front payments to source countries, but these are generally rather small sums."

Amazonian countries interested in bioprospecting are currently considering one of two options. The first is to use biodiversity as a simple money-making tool, like timber and mining concessions. "The problem with this option is that it may lead to uncontrolled exploitation, and depletion of natural



The world's most varied biota — including this ocelot — resides in the Amazon basin.

resources without generating consistent profits or technological progress," Cavalcanti says. The second option is to manage the biological resources and traditional knowledge so as to provide conservation incentives together with technological transfer, training and education.

"One of the greatest potential benefits of bioprospecting is the transfer of scientific and technological capacity," says Adalberto Luís Val, a researcher at the Brazilian National Institute for Amazonian Research (INPA), who adds that it can therefore help Amazonian countries develop beyond their traditional role as exporters of raw materials.

Major effort required

But considerable effort will be necessary to promote the process. Sérgio Ferreira, president of the Brazilian Society for the Advancement of Science, says that "a comprehensive regional assessment [of biodiversity] is needed urgently." It should go beyond sampling and building inventories, he suggests, and add value to the biological resources before they leave the country.

Major effort is also required to conserve existing biodiversity for future generations. Carlos Peres, a conservation biologist at the University of East Anglia, notes that although the current emphasis is on eco-

nomic gain, the future of the entire Amazonian biota will ultimately require its thorough characterization and preservation.

This characterization of the region's biodiversity has scarcely begun, and it is difficult to envisage the governments of the region paying for it as they struggle to address the more obviously pressing challenges of basic health care and education. José Galizia Tundisi of the University of São Carlos, who until January was president of Brazil's National Council for Scientific and Technological Development (CNPq), the country's main science funding agency, says that Brazil should invest in training more scientists. But Tundisi himself had to freeze CNPq's scholarship programme in September 1998, as a result of "having to meet other agency commitments."

Although it is unclear how science will emerge from Brazil's latest economic crisis, the country is better placed than any other in the region to build a home-grown bioprospecting enterprise. Brazil's Programme of Molecular Ecology for the Sustainable Development of the Amazonian Region (PROBEM), for example, aims to encourage bioindustry, and is backed by the federal and state governments, the scientific community, and the private sector. Dr Wanderley Messias da Costa, the programme manager, says that a US\$60 million Amazonian Biotechnology Centre, which is being built as part of PROBEM, will be strong enough to attract top scientists from Brazil and abroad. PROBEM is also creating an endowment fund for private, governmental and corporate donations, and may support venture-capital funding of biotechnology start-ups, mechanisms for patent protection and a range of other approaches designed to foster the industry in Brazil.

Science funding in other Amazonian countries has been limited and inconsistent, leaving sophisticated home-grown programmes beyond their reach. But international cooperation offers an alternative strategy. Political coordination across the region began back in 1978 with the creation of the Amazonian Cooperation Treaty (ACT), set up to promote economic development. The treaty has fostered studies and discussions, created commissions for the environment and for science and technology, and crafted bilateral agreements, all of which could, according to ACT officials, help with biodiversity management.

Academic efforts combined

The Association of Amazonian Universities (UNAMAZ) is an early initiative to combine the academic resources of all eight countries in the region. But the UNAMAZ initiative has been hampered by the lack of effective funding from the member states.

Partnerships with foreign pharmaceutical companies are another possibility for

countries in the region, who look to Costa Rica's INBio and the US-funded International Cooperative Biodiversity Group (ICBG) programme as promising examples of such collaboration. The ICBG began its bioprospecting programme in 1994 in Suriname, on the northern edge of the Amazon region. The programme there — one of four ICBG networks now established in Latin America — is led by David Kingston of Virginia Polytechnic Institute and State University, and supported by Conservation International, the Missouri Botanical Garden, the local pharmaceutical company BGVS and Bristol Myers Squibb (BMS), the US pharmaceutical corporation. "BMS will be paying Suriname US\$150,000 over five years [to reward the community]," Kingston explains. "Moreover, the project is training people, transferring technology to local research institutions, and a share of royalties from any resulting products will be allocated to each contributing party."

Sarah Laird, a researcher who has studied such programmes for the WRI and the World Wildlife Foundation, says that the region can learn from foreign pharmaceutical corporations. "They have extensive scientific expertise and a lot of capital to boost the technological and research capacities of host nations," she says.

But scientists and government officials in the region remain suspicious of these corporations, fearing that research partnerships with them will be lop-sided. "Training should extend beyond sample collection to all levels of research, and scientific information should be freely shared by all parties — neither of which is always the case," says Braulio Dias, president of the Brazilian Biodiversity Foundation. "A more proactive partnership, which is

the aim of PROBEM, is our answer."

Amazonian countries are considering laws and administrative changes to ensure that the results of research and the benefits of bioprospecting activities are shared. A legal basis for asserting, monitoring and protecting intellectual property rights is also being developed.

For example, at least two bills are being debated in the Brazilian Congress, one proposed by Senator Marina Silva and the other by the government. Silva's bill requires that foreign investigators reach a formal agreement with their Brazilian counterparts before they begin research on Brazilian soil or receive Brazilian specimens.

Scientists worry that bad laws will undermine future research, especially where it involves collaboration with foreigners. "Restrictive legislation may be unable to discriminate between bioprospecting for product development and genuine academic research," says Sir Ghilleen Prance, director of the Royal Botanical Gardens at Kew, London. It may also drive away desirable partnerships between these countries and foreign corporations. Manolo Ruiz Muller, a Peruvian lawyer currently working at Kew, says he has seen both outcomes as a result of rushed legislation by members of the Andean Pact, the trading alliance between Bolivia, Peru, Colombia, Ecuador and Venezuela.

Decision 391 of the Andean Pact places minimum, binding regulations on access to genetic resources. Muller says that the problem with Decision 391 is not so much its scope, but the inconsistency with which it is being implemented. Colombia and Bolivia have fully enacted it, Ecuador has enacted a short version of it, Peru has a drafted legislation which will be reviewed soon, and a bill compatible with Decision 391 is being reviewed in Venezuela. An 'Amazonian Par-

liament', founded by the ACT signatories, has sought to coordinate their legislative approaches.

Needs tough to anticipate

Whatever laws are in place, contracts between parties are critical. "Our ICBG experience indicates that it is very difficult to anticipate all the needs and strengths of a given agreement," says Joshua Rosenthal of the Fogarty International Center at the National Institutes of Health, who is general manager of the ICBG programme. The Peruvian ICBG agreement, for example, was set up before Decision 391 or any other Peruvian laws were in place, and its first phase was criticized for its lack of transparency and equity. The agreement was rewritten to better meet the needs of local people and the other parties involved. "We have now learned from our past mistakes and try to make our agreements more equitable," says Rosenthal. "The key is flexibility and communication among all parties."

In practice, however, the local communities, scientists and governmental representatives involved in setting up bioprospecting agreements seldom have sufficient experience to negotiate agreements, and are rarely in the financial or political position to enforce the rights they do obtain. Moreover, the benefits of intellectual property rights may be outweighed by the costs of gaining and enforcing that protection. "It is almost unfair by default," says Walter Reid. "Foreign corporations are often assisted by large teams of experienced lawyers and have sufficient financial means to deal with these situations."

To redress the balance, the World Bank has been encouraging developing countries to take a firm line in intellectual property negotiations. So it is not surprising that some countries are still erecting barriers against external exploitation of their biodiversity despite the protections they obtained under the Convention of Biological Diversity.

Seven years after the convention was signed, the sensitivity and complexity of the issues involved have intensified rather than relaxed, and Amazonian countries are still searching for solutions to the problems associated with the optimal use and protection of biodiversity.

A balanced code of scientific conduct allowing a free flow of knowledge, while preserving national and regional strategic interests, is badly needed and could be produced and implemented by biologists' professional societies. And although funds such as the Global Environment Facility, a \$US2 billion financial mechanism implemented jointly by the United Nations and the World Bank to fund environmental protection, have provided some assistance in policy making, resources are still lacking to develop the scientific and technological expertise needed in the Amazon basin.



A white uakari monkey, habitant of the Brazilian rainforest, and sub-tropical forest in Ecuador: nations of the region have sought to coordinate their approach to biodiversity conservation.

Kimberly Carr

"Cuba's future must, by necessity, be a future of scientists," Fidel Castro declared in 1960, soon after the Cuban revolution. Almost 40 years later, his prophesy is some way from fulfilment. But in one area of applied science — biotechnology — a concerted national effort instigated by Castro himself has made independent progress unmatched elsewhere in the developing world.

Until the 1960s, Cuba had no state-sponsored science programme. "Before the revolution, there were scientists in Cuba, but no science," says Gustavo Kouri, director general of the Pedro Kouri Institute of Tropical Medicine in Havana. Ismael Clark, president of the Cuban Academy of Sciences (which was founded in 1861, two years before the US National Academy of Sciences) points out, however, that Cuba has a 200-year history of outstanding scientists. The most famous is probably Carlos Finlay, a Cuban physician who in 1881 suggested that yellow fever and similar diseases could be transmitted by mosquitoes. This was the first suggestion of 'vector-borne' disease.

After the revolution, the universities were reformed to teach science, and throughout the 1960s and 1970s thousands of students were sent abroad for advanced scientific training. The first Cuban multidisciplinary research centre, the National Centre for Scientific Research (CNIC), was founded in 1965. In 1981, biotechnology work began with the production of interferon- α (see box).

Daniel Codorniú, vice-minister of science at the Ministry of Science, Technology and the Environment (CITMA), says that Cuba has invested at least US\$1 billion in biotechnology over the past 15 years. Of this year's science budget (officially US\$125 million), 30 per cent is for biotechnology-related projects. Most of this is applied research directed at developing therapies for Cuba's public health problems.

Cuban officials claim that the fruits of this research already earn enough in exports to sustain the biotechnology research pro-

gramme, although they won't provide details. Products are sold under government control and the proceeds usually go to the treasury. Agustin Lage, director of Havana's Centre for Molecular Immunology (CIM), says: "Biotechnology is not yet a major exporter like the sugar cane or tobacco industries, but it could be an important part of the economy in the future."

Export of vaccines

Most of the fledgling industry's income comes from just two products. One is a hepatitis B vaccine, now in the process of certification by the World Health Organization (WHO), which is exported to more than 30 countries. The other is the world's only known vaccine against meningitis B.

In Cuba in the 1980s, 150–200 children were dying of meningitis each year. Vaccination was carried out, but there was no vaccine against serogroup B. The A and C vaccines are based on polysaccharides in the bacterial capsule, but the polysaccharides of meningococcus B do not confer immunity in humans. So Cuba developed a vaccine using outer membrane proteins of B, capsular polysaccharides of C, and a structural protein common to both. The vaccine showed an efficacy of 83 per cent in phase II

clinical trials, and by 1990 all infants over three months old were being immunized.

Export sales were not a primary objective at the time of the vaccine's development, according to Orlando Gutiérrez of the Finlay Institute where it was developed. But Cuba began to export the vaccine in 1989, when Brazil had an epidemic of meningitis and sought help. Since then, about a dozen other countries have purchased and licensed it. The vaccine is currently being tested in Britain, and SmithKline Beecham would like to manufacture it in its Belgian vaccines division. Under its embargo policy, the United States is now trying to penalize companies that trade with Cuba, but SmithKline is seeking an exemption from such penalties.

Vaccination is a major focus of the Cuban health system, whose childhood immunization programme has led to the eradication of measles, mumps and polio, as well as a 30-fold decrease in the incidence of meningitis. Vaccine development is therefore a natural priority for Cuban biotechnology. A recombinant subunit vaccine for human immunodeficiency virus (HIV) (directed against the viral protein gp120) is in clinical trials, with a DNA vaccine in development. Also on trial are vaccines against hepatitis C, leptospirosis and cholera. There are projects to develop



How Castro's enthusiasm for biotech

In 1980, when the world was talking about interferon's promise as a potential cure for cancer, Fidel Castro made the decision that Cuba should have it too. He sent six scientists, led by Manuel Limonta, abroad

to learn how to produce interferon. A small house in western Havana was outfitted as a laboratory, and the scientists set to work. They worked non-stop, with Castro himself visiting daily to check on their progress. On the forty-second day, the laboratory produced natural interferon- α , and

Cuban biotechnology was born.

In 1982, a Centre for Biological Research (CIB) was founded near Havana, and by 1986 Limonta was the director of the Centre of Genetic Engineering and Biotechnology (CIGB), with a staff of

1,080. The CIGB is now one of a cluster of 38 pharmaceutical and biotechnology establishments located on the west side of Havana.

The CIGB has products registered in 34 countries and a total of 128 registrations worldwide. These range from diagnostic systems, vaccines and transgenic plants and animals to products for use in industrial processes. Like most of the units in the cluster, the CIGB undertakes research, development and production under one roof.

Cuba's hepatitis B vaccine was developed here. Recombinant versions of interferon- α 2b, interferon- γ , interleukin-2, epidermal growth factor, erythropoietin and streptokinase are other major exports, as is the world's only effective vaccine against cattle tick. Diagnostic systems for HIV-1 and hepatitis C are exported to Latin America, China and India, and a recombinant product for use in cheese



'Protocol 149 house' where interferon was first made.



Che Guevara (right) founded a laboratory in 1964 to research uses of sugar cane derivatives.

vaccines against *Haemophilus influenzae*, salmonella and dengue haemorrhagic fever — the last is a particularly difficult project, as vaccines must be effective against all four dengue viruses to prevent disease.

New products successful

The first scientific institute founded after the revolution was the Cuban Institute for Research on Sugar Cane Derivatives (ICID-CA), established in 1964 by Che Guevara. It was hoped then that these derivatives would some day become more important than the sugar itself, and so it is apposite that one of Cuba's most promising new products —

PPG, or policosanol — is an 8-alcohol extract of sugar cane wax.

PPG is a cholesterol-lowering drug that is safe and well tolerated even in elderly patients. Even from the early stages of development, the chemists involved thought that this product looked promising: according to Rosa Más, who directed the project, that's how it got its name. The acronym is taken from 'producto para ganar' (money-making product) — appropriately enough, as PPG is now registered in 26 countries. Most of these are developing countries, because of the competition from cholesterol-lowering drugs from first-world companies, but Castro

claims that PPG is used by patients in Miami.

Of the major biotechnology institutes, it is CIM that is doing the most basic research. Its scientists are interested in the immune system, especially its role in cancer and autoimmune disease, and they are working on developing immunotherapy for cancer.

Scientists highly favoured

The scientists in these programmes are favoured by the Cuban state. They receive about double the national average wage, and a number of fringe benefits. At the Finlay Institute, for example, senior staff are either housed on the premises, or provided with transport to and from work. Meals, clothing and child care are provided, and employees receive twice-yearly bonuses in US dollars.

"No system can advance science and technology more than socialism," Castro has declared, "because no other system can look for such integration and cooperation among all scientists, all science research centres, all professionals, all hospitals..." The country's political system certainly allows him to direct research in a way that would be impossible in most other countries. The obvious drawbacks of the system include the fact that most of Cuba's research is very applied and becoming more so. There is little room for curiosity-driven research or individual research pursuits. No one complains about any aspect of the system to outsiders, and it is unclear if they have the freedom to criticize it internally.

It is hard to say whether Cuba's approach to science and technology has been a success. If judged by citation statistics, the results are not particularly impressive. The impact factor of the average Cuban paper is 39 per cent of that of the world average, according to the Institute for Scientific Information (ISI) in Philadelphia, compared with an average of 55

per cent in the rest of Latin America. The impact factor of Cuban papers has doubled over the past 12 years, however, and it is higher in some areas: in pharmacology, for example, the impact factor is a respectable 87 per cent of the global average.

Castro oversaw the establishment of the CIB in person.



But despite a difficult situation, exacerbated by the US embargo, the scientists are clearly doing good work. They have had some commercial success with their products, and have won the respect of those in the international community who collaborate with them. Perhaps most impressively, life scientists have succeeded in addressing several important public health problems with modest resources and little access to the ideas or materials available in the rest of the world.

spurred vaccine development

production is now being licensed in Spain.

Vaccine projects include vaccines for HIV-1 and hepatitis C (both now in trials) as well as human papilloma virus (HPV), dengue haemorrhagic fever, and a recombinant version of the meningitis B vaccine developed by the Finlay Institute.

Plants including sugar cane, papaya, potato, coffee, cabbage and tomato are being genetically modified at the institute for increased resistance to pests and disease, and transgenic sweet potatoes with an improved amino-acid balance are being developed. Development of transgenic sugar cane with a lower lignin content and a higher sugar yield is under way, as sugar cane fibres are used widely for paper and animal feed, and a high lignin content reduces their suitability. Field trials take place following internationally recognized safety guidelines, institute staff claim.

Staff are also working on cloning rabbits and cattle, using the nuclear

transfer technique that produced Dolly the sheep. More traditional transgenic approaches have been used to produce mice and rabbits that express human proteins such as tissue plasminogen activator, growth hormone and erythropoietin in their milk. And transgenic fish have left the laboratory for supermarket shelves: last year 30 tonnes of transgenic tilapia were produced.

There has been no adverse public reaction to these genetically modified foods, although it would be difficult for anyone with doubts to express them in Cuba. Science and biotechnology are, after all, priorities of the revolution. "People trust science; they've seen how it has improved their lives," says Limonta.